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Noise Levels in the USAARL NUH-60 (Black Hawk) Aeromed Flight Simulator

by Elmaree Gordon and William A. Ahroon

Aircrew Protection Division

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Noise levels in the NUH-60 (Black Hawk) Aeromed Flight Simulator located at the U.S. Army Aeromedical Research Laboratory were measured. Noise levels were adjusted using a nine-position control set by the simulator operator. The simulator operator's manual stated that noise levels should not exceed 85 dBA. Measurements were made at five noise level settings at the pilot and copilot stations. Results showed that the A-weighted sound level of the flight simulator at Noise Level Setting 1 was 81.8 dBA while levels at Settings 3, 5, 7, and 9 exceeded the 85 dBA noise exposure limit. In addition, the octave-band frequency spectrum of the simulator noise at Setting 9 differed appreciably from the spectrum of an actual UH-60A aircraft. These differences were particularly large (exceeding 20 dB) in the upper frequencies in the speech range and should be considered before similar research involving communication or speech intelligibility is conducted. It is noted that noise hazard signs are posted appropriately at the entrance to the USAARL NUH-60 flight simulator in accordance with MIL-STD-1474D "Noise Limits." Hearing protective devices should be used in the simulator when operated at noise levels above the lowest noise level setting.

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Introduction

Sound pressure levels inside military helicopters during flight almost always exceed the noise exposure limits established by the Department of Defense Hearing Conservation Program criteria (DODI 6055.12, 1991). Noise levels during some flight conditions exceed the capabilities of the required hearing protective devices, helmets and earplugs, to provide effective hearing protection and maintain effective voice communication in the aircraft. The United States Army Aeromedical Research Laboratory (USAARL) has been investigating various techniques to reduce noise exposure for the helicopter crewmember and improve voice communication in even the noisiest conditions. Since military helicopter pilots receive much of their training in flight simulators, assessment of some noise reduction and voice communications techniques may be conducted in the USAARL Black Hawk flight simulator. It was, therefore, necessary to measure actual sound pressure levels in the simulator cockpit.

According to the simulator's technical/operator's manual (TM 55-6930-217-10, 1989), environmental sound cues are available at nine levels and are limited to a maximum of 85 dB. However, there is no readily-available test data documenting the noise levels or spectra in the simulator cockpit. In this study, we measured sound pressure levels in the USAARL NUH-60 (Black Hawk) Flight Simulator cockpit at five noise level settings. These data were compared with sound pressure levels measured in a UH-60A Black Hawk Helicopter (Mace et al, 1981) to determine the simulator noise level setting that would best duplicate the actual UH-60A helicopter flight environment.

Flight simulator

The UH-60 Black Hawk flight simulator is a fixed-base, full-motion simulator and is designed to be used for training in aircraft control, cockpit preflight, start, run up, shutdown, normal and emergency procedures, instrument flight operations, visual flight operations, sling-load operations, external stores subsystems, night vision goggles, Doppler and Global Positioning System operation, nap-of-the-earth flight, low-level flight, and contour flight.

The USAARL NUH-60 (Black Hawk) Aeromed Flight Simulator (Figure 1) has been permanently modified for the collection of aeromedical data during helicopter flight simulation over a range of controlled environmental conditions, but also can be used for training aviators in the use of the UH-60A/UH-60L Black Hawk helicopter. Primarily used for aeromedical research, the USAARL NUH-60 provides a means of safe exposure of the pilot and copilot to adverse flight conditions under controlled and monitored conditions. The simulator is instrumented for the collection of a wide range of aeromedical research data. A central computer system controls the operation of the simulator complex and provides for storage of data on a computer for later analysis.

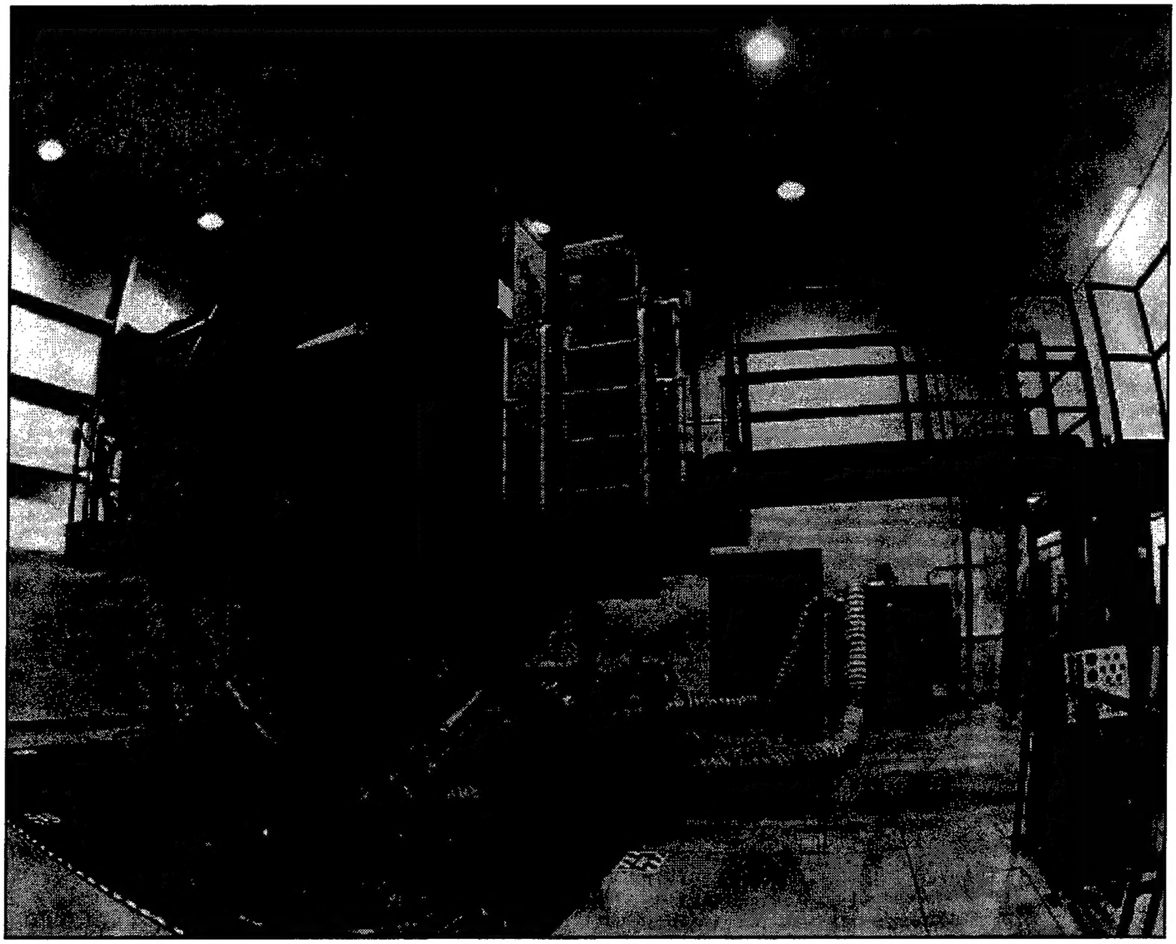

Figure 1. Exterior view of the USAARL NUH-60 (Black Hawk) Aeromed Flight Simulator.

The flight simulator compartment houses a cockpit with pilot and copilot stations (Figure 2) and is isolated from the instructor/operator station (IOS), and observer station. Communication among between the operator, observer, and cockpit occupants is provided through an administrative intercommunication system (ICS) network. Pilot and copilot performance is monitored at the IOS. The simulator is equipped with a full-color visual system, combined with digitally- generated imaging that simulates natural helicopter environment surroundings.

Analog sound generation is provided under computer control. Several loudspeakers in the cockpit simulate aural cues provided by the actual aircraft. Environmental aircraft sound is available at nine levels, selected at the control console by the simulator operator. The motion system provides cues of pitch roll, yaw, vertical, longitudinal, and lateral. The pilot/copilot seats are vibrated individually to simulate both continuous and periodic oscillations and vibrations experienced by the crew during normal and emergency flight conditions and maneuvers,

including vibrations representing progressive malfunctions. Both motion and vibration are selected or deselected at the IOS.

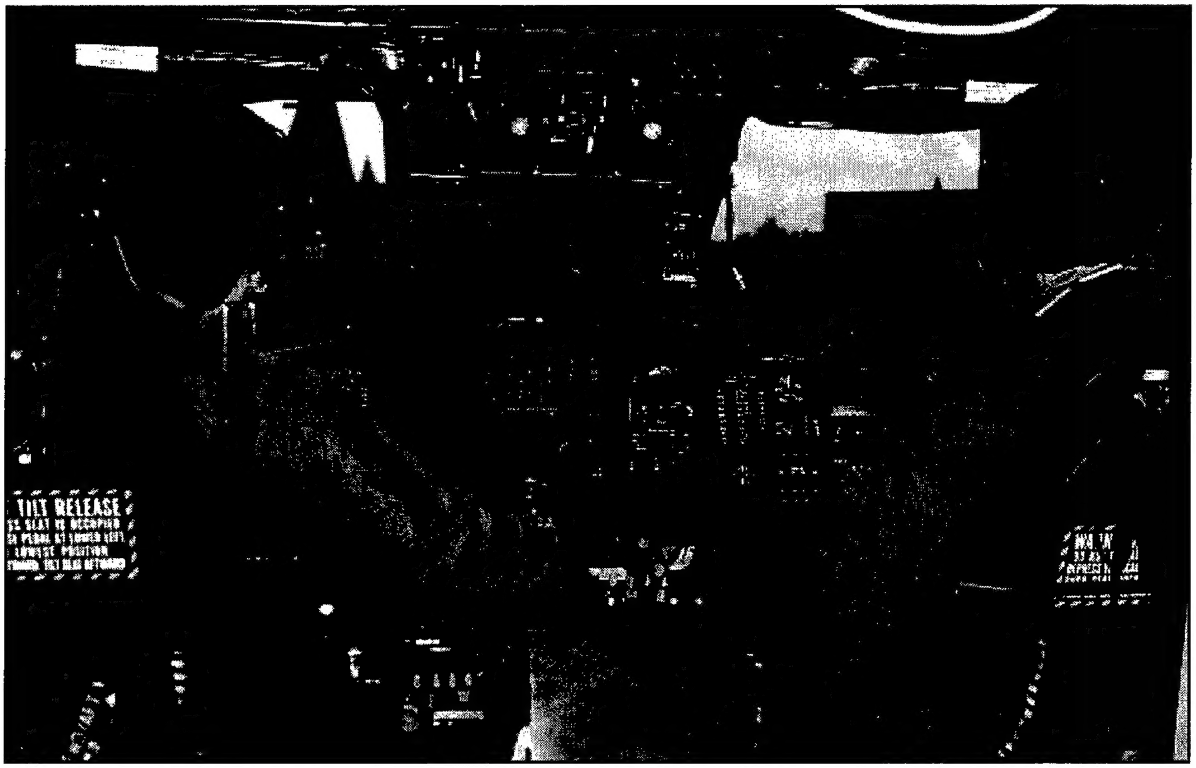

Figure 2. Cockpit of the USAARL NUH-60 (Black Hawk) Aeromed Flight Simulator. Note that noise measurements were made without crewmembers present

Methods

Measurements were made in the USAARL NUH-60 (Black Hawk) Flight Simulator, Serial Number 85-00009. From the control console, the operator ran the simulator at "flat-pitch" operation, with main rotor speed at 100 percent, collective at full-down position, and cockpit doors closed, simulating operation of the aircraft on the ground in preparation for flight. In accordance with MIL-STD-1474D (1997), measurements were made without crewmembers in the cockpit. The measuring microphones were placed at pilot (right seat) and copilot (left seat) center-of-head locations, at a distance of 80 centimeters above the seat reference, as specified in MIL-STD-1474D (1997). Measurements were made at noise level settings 1, 3, 5, 7, and 9.

Sound pressure levels in the cockpit were measured using two Brüel and Kjær (B&K) Type 4165 ½-inch free-field microphones. Each microphone was coupled to a B&K Type 2639 microphone preamplifier. Each preamplifier was coupled to one of the four independent

channels of a B&K Type 5968 acoustic front-end. The output of each channel of the acoustic front-end was coupled to one of four independent channels of a SONY Model PC204A DAT instrumentation cassette recorder. The recording system was calibrated to absolute sound pressure level using an acoustic reference signal produced by a B&K Type 4220 pistonphone. Two minutes of simulator noise at each noise level setting were recorded. Octave-band and overall A-weighted levels were measured offline by running the recorded signal through a Larson-Davis Model 3100 Real-time Analyzer.

During recordings, the simulator operator wore a protective communications headset and the research investigator wore a protective communications earplug (CEP). Sound pressure levels at the simulator IOS and observer station were not measured.

Results

Table 1 shows octave band sound pressure levels, with center frequencies from 31.5 Hz to 8000 Hz and A-weighted sound levels, measured at the pilot and copilot locations in the UH-60A helicopter during 120 knot cruise with doors closed. Sound pressure levels in octave bands with center frequencies from 31.5 Hz to 8000 Hz and A-weighted sound levels in the USAARL NUH-60 flight simulator measured at the five noise level settings for pilot and copilot locations are shown in Table 2. Sound pressure levels at the pilot and copilot locations are virtually identical at each simulator noise level setting and in the helicopter. Therefore, only the pilot data are referenced throughout the rest of this report.

Figure 3 shows sound pressure levels at the NUH-60 pilot location at the five noise level settings measured. The A-weighted levels for the five noise level settings measured at the pilot location are shown in figure 4. Only noise level setting 1, at 81.8 dBA, is below the 85 dBA limit defined in DODI 6055.12 (1991). Sound pressure levels at settings 3, 5, 7, and 9 exceed this limit. The A-weighted levels of the simulator at noise level setting 9 and the helicopter at 120 knots are within 2 dBA of each other. At noise level setting 9, simulator sound pressure levels are lower than the helicopter sound pressure levels by about 6 dB at 1000 Hz, 13 dB at 2000 Hz, 21 dB at 4000 Hz, and 10 dB at 8000 Hz (Figure 5).

Discussion

One important observation made in this report is that the 85 dBA noise exposure limit established by Army regulation is exceeded at all but the lowest measured noise level setting. Therefore, care should be taken to ensure that crew occupants of the USAARL NUH-60 flight simulator wear hearing protection any time it is operated at any of the higher noise level settings.

Ideally, for noise and speech research to be performed in the simulator, noise spectra during flight simulation should be the same as the helicopter across the frequency spectrum. However, at some frequencies, the USAARL NUH-60 simulator differs considerably from the UH-60A helicopter (Figure 5). The 40 dB difference at 31.5 Hz may be due to the absence of rotor blade noise. Aerodynamically-generated noise is created at the rotor blade pass frequency of 17 Hz with a harmonically-related repetition occurring near 31.5 Hz. More importantly, in the speech range, 1000 Hz to 4000 Hz, as mentioned above, simulator levels are considerably lower than the helicopter noise. These differences in frequency spectra should be considered before proceeding with research involving speech stimuli. The addition of small portable audio loudspeakers did not change the noise spectra of the simulator. Since the USAARL NUH-60 simulator is maintained by contractor services, it was also determined that adding additional permanent audio speakers to the cabin involved a level of expense and difficulty beyond the added value of altering the structure of the simulator.

Table 1.
Sound pressure levels in dB for each octave band center frequency shown and A-weighted sound levels at the pilot and copilot locations in a UH-60A Black Hawk helicopter during 120 knot cruise with doors closed.

	Frequency (Hz)									
	31.5	63	125	250	500	1000	2000	4000	8000	dBA
Pilot	108	100	102	107	96	91	88	85	85	101
Copilot	112	101	101	100	94	89	88	84	83	97

Table 2.

Sound pressure levels in dB at noise level settings 1, 3, 5, 7, and 9 for each octave band center frequency shown and A-weighted sound levels at the pilot and copilot locations in the USAARL NUH-60 (Black Hawk) Aeromed Flight Simulator during flat-pitch operation, main rotor speed 100 percent, collective full down, and cockpit doors closed.

	Frequency (Hz)									
Level setting	31.5	63	125	250	500	1000	2000	4000	8000	dBA
Level 1										
Pilot	67.2	78.8	84.6	90.7	75.5	69.6	66.1	60.1	58.4	81.8
Copilot	66.9	79.9	86.0	90.1	75.1	70.4	65.0	58.4	56.8	81.4
Level 3										
Pilot	68.0	85.9	91.9	98.0	82.6	75.4	67.6	60.4	62.9	88.9
Copilot	67.5	87.4	93.6	97.6	81.6	76.8	67.4	58.8	62.5	88.6
Level 5										
Pilot	68.9	90.8	96.9	103.4	87.6	80.0	69.9	61.1	67.8	94.0
Copilot	68.3	92.2	98.6	103.0	86.6	81.4	70.8	59.9	68.5	93.9
Level 7										
Pilot	69.3	93.3	99.4	106.3	90.8	83.2	72.6	62.3	72.3	97.0
Copilot	69.2	95.1	101.2	105.9	89.8	84.6	73.7	61.5	70.8	96.8
Level 9										
Pilot	70.0	94.8	101.0	108.0	92.5	85.3	74.9	64.1	74.8	98.8
Copilot	70.6	96.7	102.9	107.7	91.5	86.5	76.1	63.3	73.0	98.6

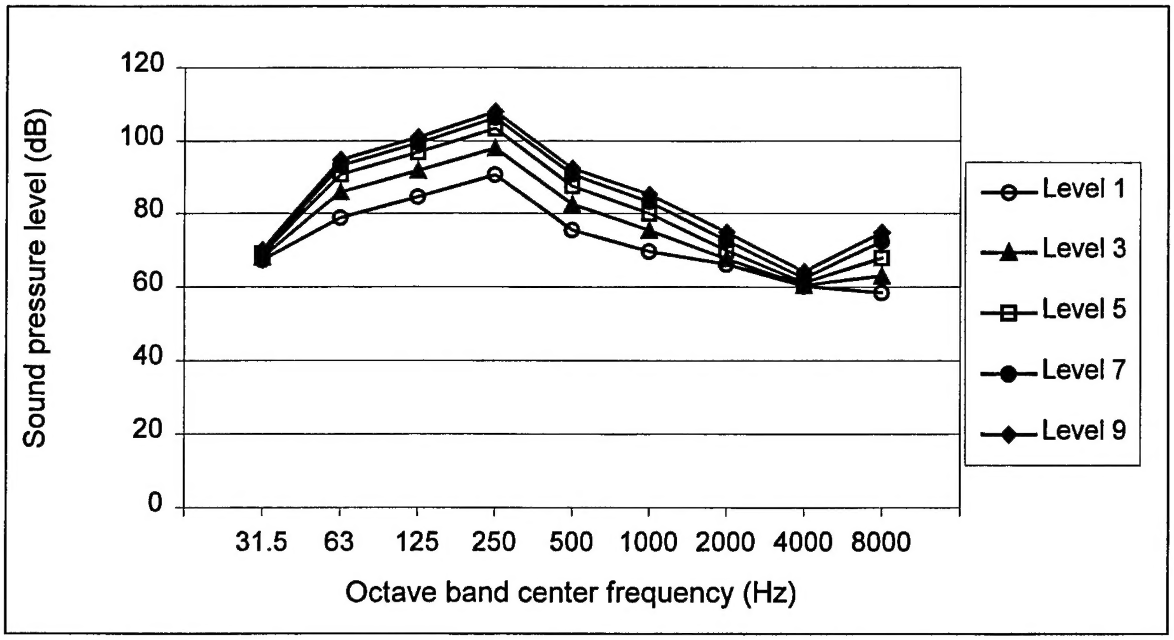

Figure 3. Sound pressure levels in the USAARL NUH-60 (Black Hawk) Aeromed Flight Simulator at noise level settings 1, 3, 5, and 9, at pilot location, during flat pitch operation with main rotor speed at 100 percent, collective full down, and cockpit doors closed.

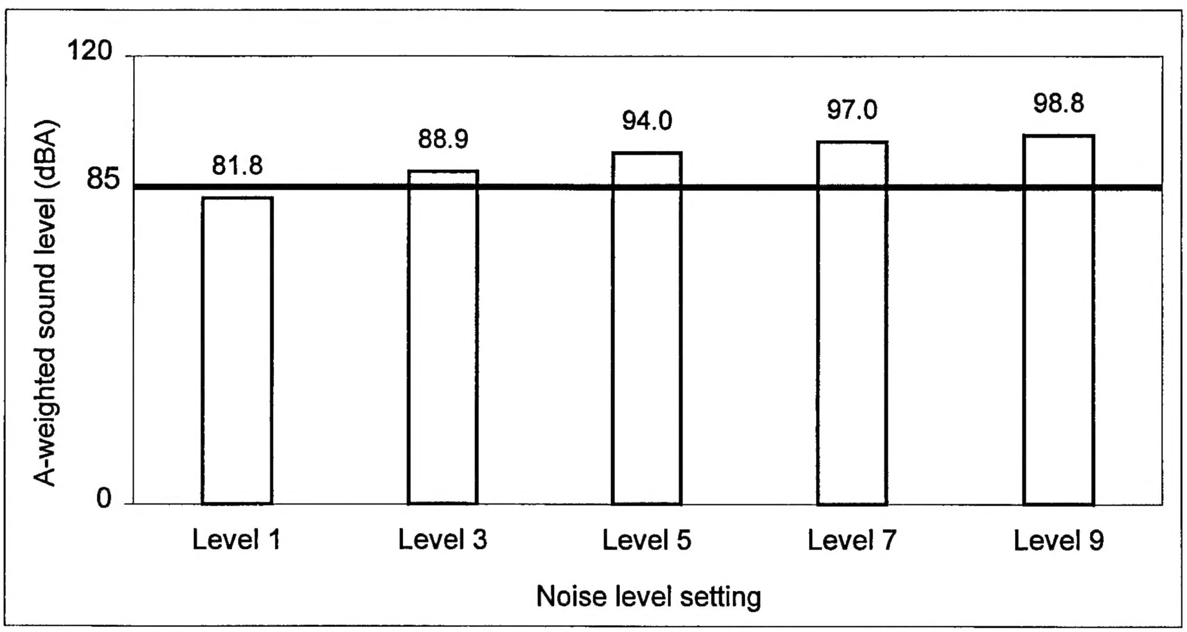

Figure 4. A-weighted sound levels in the USAARL NUH-60 (Black Hawk) Aeromed Flight Simulator at five noise level settings, at pilot location, during flat pitch operation with main rotor speed at 100 percent, collective full down, and cockpit doors closed.

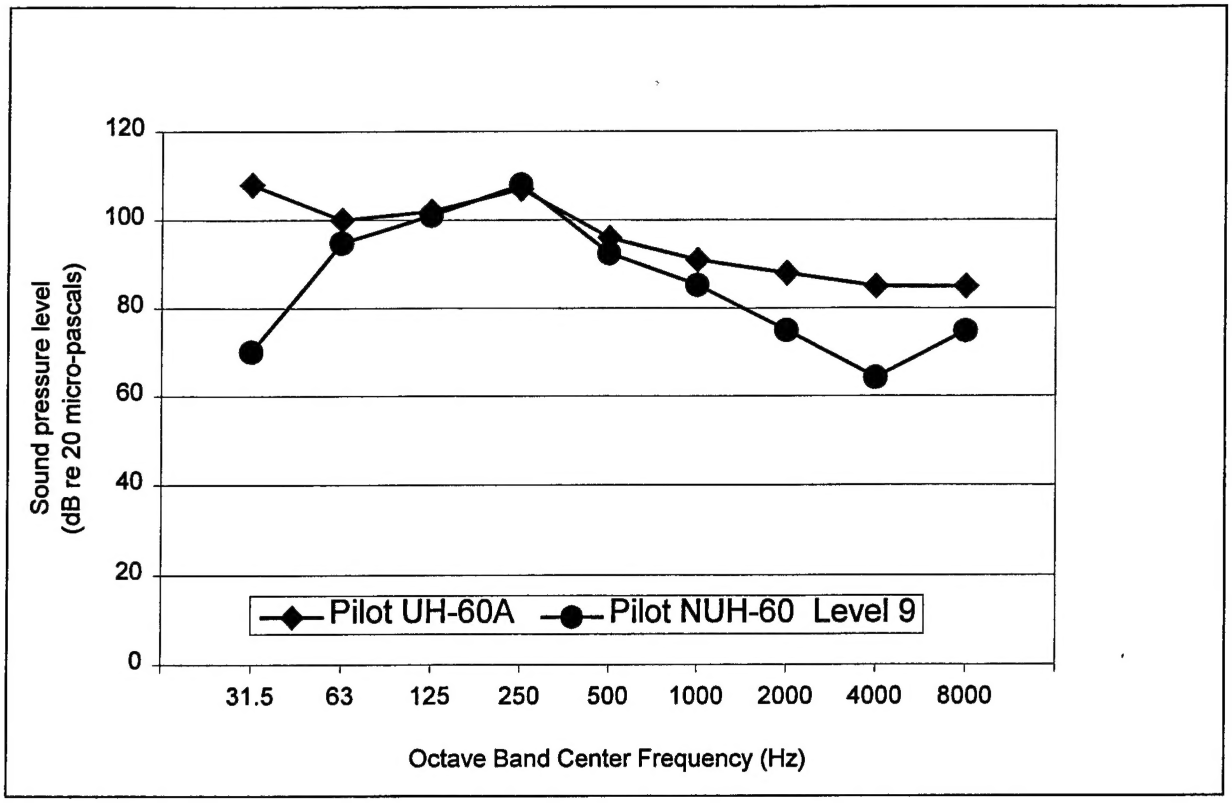

Figure 5. Sound pressure levels in the USAARL NUH-60 (Black Hawk) Aeromed Flight Simulator at noise level setting 9, at pilot location, during flat-pitch operation with main rotor speed 100 percent, collective full down, and cockpit doors closed, and a UH-60A helicopter at pilot location, during 120-knot cruise with doors closed.

Conclusions

Standard flight simulator training and most USAARL research protocols in the USAARL NUH-60 simulator are conducted at noise level setting 1, which is below the 85 dBA limit. All other noise level settings measured during this study exceed the 85 dBA limit.

It is noted that noise hazard caution signs on the USAARL NUH-60 simulator are posted appropriately as specified in MIL-STD-1474D. It is recommended that volunteers participating in research protocols that require operation of the simulator at or above noise level setting 3 should be required to wear protective helmets, muffs, or earplugs. Any one of these hearing protective devices meets the requirements for protection against sound pressure levels that exceed the limit as specified by Department of Army Hearing Conservation policy (DA PAM 40-501, 1991).

When considering future research that may be performed in the USAARL NUH-60 flight simulator, the difference in energy spectra compared to the UH-60 aircraft should be considered

before proceeding with research involving speech stimuli. Ideally, such tests would be conducted in a helicopter; but the necessity for a controlled flight environment precludes conducting such tests in an aircraft. However, where there is a requirement for the UH-60 flight environment and accomplishment of tasks typically required during flight, the USAARL NUH-60 flight simulator provides a controlled and monitored flight environment for testing some noise reduction and speech communications techniques.

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